On Noise
A Philosophical Critique of the Notion of Noise in Shannon's Theory of Communication

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The notion of noise as presented in much humanities scholarly works is rooted in engineering and the seminal work of Claude E. Shannon titled "A Mathematical Theory of Communication" - published in 1948. What did the paper say about noise? In all, the narrowness of a mathematical understanding of noise presents severe limits but also possible openings, directions or bridges towards the non-mathematical.

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"A Mathematical Theory of Communication", published in the Bell Systems Technical Journal in 1948 [3], is the seminal work of Claude E. Shannon with which, building on the work of Nyquist and Hartley, the domain of information theory was founded. The influence of this work would soon to be felt outside the engineering domain and reaching humanities discourse and more importantly media theory, media arts and philosophy.
His second paragraph describes succinctly and with immense clarity the problem at hand. Here is the excerpt:

> The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point.

In this sentence we can find the now classical understanding of communication as information or data travelling from a sender to a receiver. Such a clarity of the enunciation is achieved at the expenses of the complexity intrinsic to all kind of communications. That is to say that the problem of communication thus proposed was limited in its scope as an engineering problem and nothing more. Shannon was very clear with regards to the remits of his work. Any use of his theories outside those remits will/should have had to confronts the narrowness of its original scope:

> Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages.

This is important. Shannon's theory of communication is not concerned with meaning or semantics but only with the probabilities involved in the successful interpretation of data parsed from one point to another through a medium. Communication is to be understood as a mere parsing of data.

Though an engineering problem, Shannon's theory of communication provided much food for thought for humanities scholars. The ever-increasing and pervasive role of technological media into human affairs would have made unwise to ground any discourses on media without the inclusion of its technical analysis. By way of an eminent example, McLuhan's motto "the medium is the message" is inspired by the work of Shannon. The medium, the channel in Shannon's parlance, is what really counts in communication. Any message conveyed through a medium by a conscious subject, and any meaning extricable from a conscious individual at the receiving end, is inexorably altered by the overpowering presence of the medium itself. In that sense the medium's accuracy/capacity of parsing information affects the ultimate meaning one wishes to conveyed or interpret. Senders and receivers are belittled by the presence of the electrical light.

Kittler, as another notable example, pushes too on this dominating aspect of technology over human affairs but he also defend a position for which meaning should not be thought of as something given a priori, as McLuhan does, but rather as something emerging from our relationship with the materiality of the medium - meaning, if one wants to be concerned with it, is only the result of the reading of a system, or network, parsing information. [1].

In this context, Kittler's position is closer to Shannon's not only because the role of "meaning" is greatly diminished but also because he, overall, understood better the mathematics of Shannon's theory[2]. Yet, as I will care to argue, this is not necessarily an advantage.

However, as mentioned already, Shannon's theory of communication provided much food for thought to non-engineering disciplines also, and most importantly, because it offered a useful conceptual map of the process of communication. Figure 1 shows such a map (with original caption included) - a map that will influence media theory, philosophy, arts and much more and to which many authors will come back to (Eco, Hayes, Serres ...) .

[1] `https://monoskop.org/images/3/3e/Gane_Nicholas_2005_Radical_Post-humanism_Friedrich_Kittler_and_the_Primacy_of_Technology.pdf`

[2] Kittler's proficiency in technical disciplines was well-known

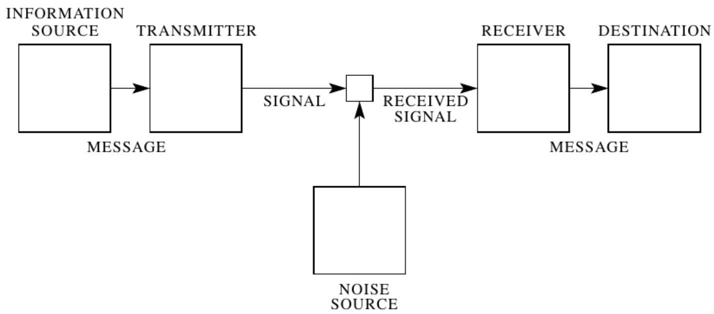

Fig. 1—Schematic diagram of a general communication system.

Figure 1: Original schematics of communication system as depicted by Shannon in ref

Shannon describes the figure as made up of five parts: 1) an information source e.g. a teletype sentence, TV/Radio signal etc. 2) a transmitter - essentially a coder 3) a channel enabling the transmission of the coded signal 4) a receiver - i.e. a decoding device 5) "the person (or thing) for whom the message is intended".

The reason why Shannon's theory can do away with meaning and semantics is because an information source is not a person. What concerns Shannon is not the meaning of what is communicated but its form. For example, a sentence is only a group of words and letters put together according to the rules of the system to which they belong (i.e. a language). The fact that Shannon consider the Destination as being either a person or a thing is only a veiled, unexplored and possibly naive opening to the possibilities of cybernetics. Yet this definition clarifies how it inspired and legitimised both McLuhan and Kittler's diverse views.

There is, what I believe to be, a curious feature in Shannon's description of these five elements and it concerns noise. Noise appears in the picture but, curiously, in the text is presented as disturbance under what is listed as "channel". Here is the full definition:

> The channel is merely the medium used to transmit the signal from transmitter to receiver. It may be a pair of wires, a coaxial cable, a band of radio frequencies, a beam of light, etc. During transmission, or at one of the terminals, the signal may be perturbed by noise. This is indicated schematically in Fig. 1 by the noise source acting on the transmitted signal to produce the received signal.

At this points, we know what noise does - it disturbs - but not what it is. Noise disturbs the transmission of a message between a transmitter and a receiver. A sort of trick of God who decided to throw a spanner in the works. A definition though comes at page 19 and goes as:

> The noise is considered to be a chance variable just as the message was above.

For Shannon, noise is nothing more that a mathematical variable, just as a variable is the information source in his analysis. The narrowness of his scope requires such synthesis. His words are, once again, very clear:

> We wish to consider certain general problems involving communication systems. To do this it is first necessary to represent the various elements involved as mathematical entities, suitably idealized from their physical counterparts.

Can anyone one think of a better example than this one (after Galileo of course) when it comes to what Husserl calls the "mathematisation of nature"?

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To the risk of sounding ridiculous, it is obvious that a theory of communication grounded on statistical analysis cannot accept certainty. Theorem 2 states exactly that:

$$H = -k \sum_{i=1}^{n} p_i \log p_i$$

H is the "measure of how much "choice" is involved in the selection of an event or of how uncertain we are of the outcome". In other words, it is the probability with which we can tell what the sent message is and the rate with which information is produced. H is the measure for the information source in probability terms. That is, it is the measure of the choice and uncertainty between possible messages without considering any medium of transfer. The interesting part is that H must always be positive - i.e. there must be some uncertainty. This also means that in the limit case of $H = 0$ we would have certainty and with certainty we nullify the need for any channel - i.e. no uncertainty means no channel or medium. For example:

> If a source can produce only one particular message its entropy is zero, and no channel is required.

Following from the previous formula, H is 0 "if and only if all the p_i but one are zero, this one having the value unity. Thus only when we are certain of the outcome H vanishes. Otherwise H is positive."

Interestingly, all this is explained in a chapter that Shannon titles as "Discrete Noiseless Systems". What interests me is that in this preliminary part of his analysis Shannon is only concerned with information source and destination while discarding the channel. And yet we need uncertainty to be able to talk about communication and channels. In doing so, what he is implicitly telling us is that **"noiseless" is another word for "channel-less"**. In other words, noise is not just a dispensable element of a system of communication but a necessary and intrinsic one for at least two reasons: 1)statistical methods are useful as long as noise is present (i.e. $H < 0$) and 2) there can be no channel without noise.

Hence it would be legit to ask: can there be mediation without noise? The answer would be "no, because there would be nothing to mediate". Can there be communication without noise? No, because there would be nothing to share. With regard to Shannon's work, it would be then more apt to state the following: **a channel is a mathematical representation**

of a conduit of noise, a message is just what survives it. Outside mathematics and schematics we could more simply state: **Channel is noise while noise is not channeable**.

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Theorem 2, $H = -k \sum_{i=1}^{n} p_i \log p_i$, is also interesting for another case, namely the one in which all instances of $p_{i1,i2...in}$ would equal 0. In such circumstance, H becomes undefined [3], meaning that H is only an ever-approaching but never-reaching mathematical idealisation of *pure* noise/uncertainty/chaos - where *pure* means "beyond any possible mathematisation of the phenomenon".

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The second part of Shannon's essay is concerned with discrete channels of communications in the presence of noise. In this part of the essay Shannon includes noise as a mathematical variable (rather than being a necessary and implicit element of the system as I cared to argue previously). By including noise as mathematical variable, the received message E at the receiving end is described as a function of two variables: the sent message S and the channel's noise N.

$$E = f(S, N)$$

The probabilities intrinsic to the communication channel are described as the combination of the entropy of both the information source and the receiving end. The formula is:

$$H(x, y) = H(x) + H_x(y) = H(y) + H_y(x)$$

where:
$H(x)$ is the entropy (i.e. noisiness) of the information source;
$H(y)$ is the entropy (i.e. noisiness) of the receiving end;
$H_x(y)$ is the entropy of the output when the input is known;
$H_y(x)$ is the entropy of the input when the output is known and it is also called "equivocation" - the average ambiguity of the received signal.

In this instance, noise characterises the whole communication chain. Noise is present at the input, output and in the channel bridging input and output. Shannon's theory is a theory that aims to establish within what probabilities we can successfully establish a communication between two parties. Shannon's theory of communication is, as the title correctly tell us, a *mathematical* theory of communication.

Following from the previous formula, Shannon introduces Theorem 10 stating that:

[3] $log(0)$ is undefined

> If the correction channel has a capacity equal to $H_y(x)$ it is possible to so encode the correction data as to send it over this channel and correct all but an arbitrarily small fraction of the errors. This is not possible if the channel capacity is less than $H_y(x)$.

This means that in order to enhance our probability to reconstruct correctly the message sent we need to ensure that the capacity of the channel is greater than the entropy of the input when the output is known. As Shannon states then, " $H_y(x)$ is the amount of additional information that must be supplied per second at the receiving point to correct the received message."

From another perspective, if we are ready to consider this additional information as **pseudo-noise** (i.e. man-made/controlled/correlatable noise), it would seem that we have yet discover another reason for **the unavoidable necessity of noise in communication** and that **communication is just a pattern-searching process into a noise field or noisy universe**

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From this, **Shannon defines the capacity C of a noisy channel as the maximum rate of transmission achievable** and defined as:

$$C = Max\left(H(x) - H_y(x)\right)$$

where, to be sure:

$H(x)$ is the entropy of the information source alone; and

$H_y(x)$, also called the equivocation, is the average ambiguity of the received signal.

Two things should be bared in mind here: the relationship between entropy and the rate of transmission. Capacity is thought of as both statistical value determining the probability for a variable to be in a state rather than in another and the rate with which that value can change. The relationship between $H(x)$ and $H_y(x)$ is explained by Shannon with the figure presented below:

This picture tells us that the **rate of information produced by a source - $H(x)$ - is always greater than the rate (and certainty) with which the receiver will be able to interpret it - $H_y(x)$ or equivocation**. This is inline with what stated so far because in order to maximise capacity with need to have $H_y(x)$ approaching (but never reaching zero) 0 so that the rate of successful (certitude of correctness) transmission is approaching $H(x)$ - the original source. In other words, we increase pseudo-noise with redundancy while attempting to minimise (but never eliminate completely) uncertainty or statistical noise. The limit case for which $H_y(x) = 0$ would be again the case of a noiseless (hence channel-less) system.

It is at this point that Shannon states something really interesting:

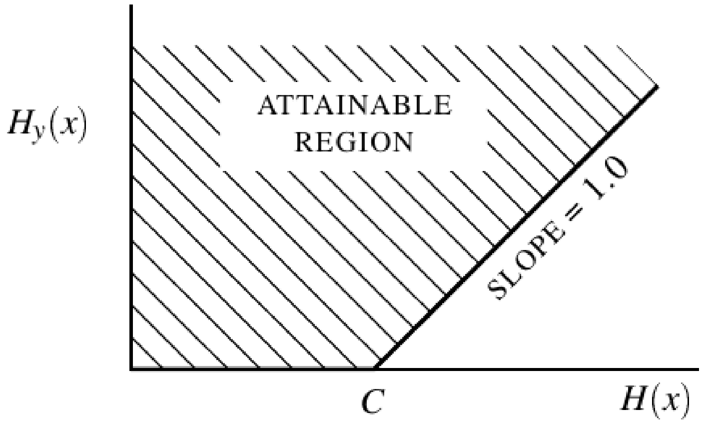

Figure 2: —The equivocation possible for a given input entropy to a channel. (original caption)

> Actually the capacity C defined above has a very definite significance. It is possible to send information at the rate C through the channel with as small a frequency of errors or equivocation as desired by proper encoding. This statement is not true for any rate greater than C. If an attempt is made to transmit at a higher rate than C, say $C + R_1$, then there will necessarily be an equivocation equal to or greater than the excess R_1. **Nature takes payment by requiring just that much uncertainty**, so that we are not actually getting any more than C through correctly.

In what highlighted in red lies a very important acknowledgment by Shannon: there is noise outside noise that cannot be claimed by or accounted for by men and women, their logos and culture.

The remaining part of Shannon's essay extends the discussion to continuous channels of transmission (as opposed to the discrete channel discussed so far). No new interpretations of the idea of noise are introduced though. I wish then to stop here the overview of his essay and expand instead on the diverse uses of the concept of noise presented so far.

Thoughts on Noise

Many and diverse uses of the word "noise" have been mentioned to this point. Overall, it is possible to divide these definitions in two macro groups - one for which noise is a mathematical concept (■) and one for which it is not (■). Allow me to recapitulate them.

- ■ Noise as disturbance.
- ■ Noise as unavoidable and necessary feature of a channel.
- ■ Noise as mathematical variable.

- ■ Noise as chance variable.
- ■ Noise as entropy of an information source.
- ■ Noise as entropy at a channel's receiving end - aka equivocation.
- ■ Noise as error.
- ■ Noise as redundancy of information.
- ■Noise as uncertainty claimed by nature.

Noise is a mathematical variable and as such it is described in terms of the entropy of a system or a part thereof. Noise, then, is a stochastic variable concerned either with the probability of a given outcome or, conversely, with its uncertainty. In broad terms, entropy is the measurement of uncertainty in a given system. For that, entropy connects to the randomness with which something might occur. It is clear how a definition of noise blurs across multiple terms such as entropy, randomness, uncertainty, chaos and more generally disorder. All these terms means different and precise things in mathematics and physics with that domain-narrowness energising their meaning. Mathematics requires a narrowness of focus in its explanation of phenomena by means of variables, symbols and logic. The solidity of its discourse is not granted by the soundness of its proofs but by the non-provability of its axioms.
For Shannon, noise is a mathematical idealisation of a phenomena. But what phenomenon is he referring to? Does noise belong to the sphere of perceivable phenomena? In Shannon case, noise is experiential in so far it is measurable. It enters the phenomenal sphere for its effects on of what we can see, hear or, more importantly, count. Hence, it does not matter what the real source of that noise is as long as "what is" is measurable or countable in statistical terms. Shannon deals exclusively with a calculable world where communication has been mathematicized.

And yet Shannon mentions noise as something else, something extra, something disturbing and interfering on an otherwise "clean" process. Figure 1 depicts this by placing noise outside the linear left-to-right flow of information. Hence one would be inclined to question the origin of such a disturbance. Where does it come form? What is it made of? Why? etc. But the drawing does not yield nor pretend to visualise any ontology of noise. Shannon is simply concerned with visualising what happens, namely "something" that mess with communication in the space in-between sender and receiver.
At the same time, one cannot do but to note that the drawing is imprecise even in light of Shannon's understanding of noise. As I have highlighted earlier, noise is a variable necessary to define not only the space in between but every element of a communication system, even "noiseless" ones: from the information source to the destination.

Noise, it seems, is everywhere so that perhaps a more faithful drawing would see communication as the mere leftover, or discoverable pattern, within a noise field. Thus noise is not an extra partes affecting the communication process but intrinsic and necessary to it - as indeed Shannon highlights too (i.e. no noise means no [need for a] channel or medium).

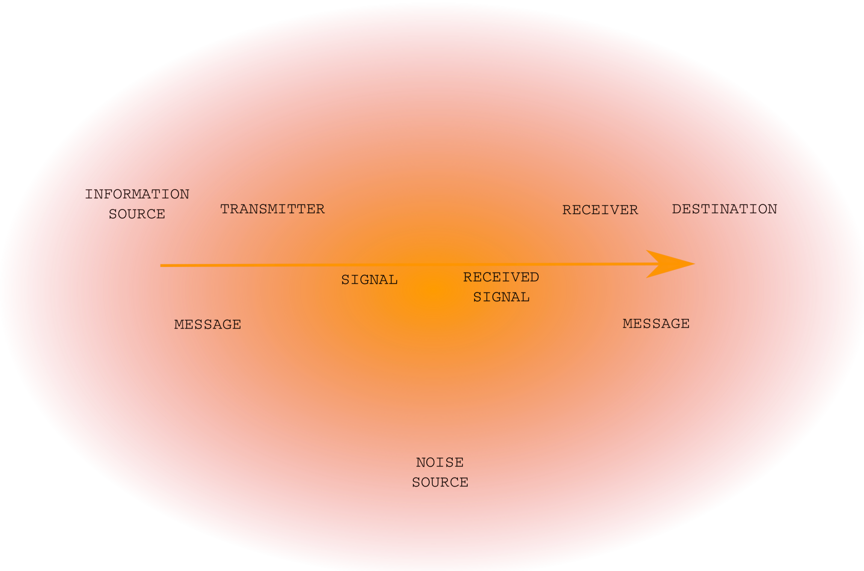

Figure 3: Another way of depicting a communication system in light of the intrinsicality of noise.

Under these circumstances, we could consider any **communication as that negative image emerging from noise.** Noise, then, is not disturbance or interference but simply *what is*, while communication what we can know with an approximate degree of certitude. Simply put, we could not know anything if noise did not permeate what we know.

To be sure, noise is neither the *uncertainty claimed by Nature*, the extra mathematical, that Shannon hints to. If it was, we would have only followed a Cartesian reasoning to the identification of noise as absolute chaos, in fact an *hyper-Chaos* also incapable of "guaranteeing the absoluteness of scientific discourse" [2, p. 64]. Meillassoux:

> ...what we see there is a rather menacing power - something insensible, and capable of destroying both things and worlds, of bringing forth monstrous absurdities, yet also of never doing anything, of realizing every dream, but also every nightmare, of engendering random and frenetic transformations, or conversely, of producing a universe that remains motionless down to its ultimate recess, like a cloud bearing the fiecest storms, then te eeriest bright spells, if only for an interval of disquieting calm. (ibid, p.64)

On these groundings, Meillassoux posits: "how could such a disaster provide the foundation for scientific discourse?". How, in fact, could we provide solid groundings for any kind of knowledge at all? The answer that Meillassoux provides is a fold-back to the necessary contingency of mathematical statements that are then able to asserts the existence of objects, law or worlds without the contingency of a thinking being. After the finitude of the human experience then, there is a non-metaphysical absolute *structure of the possible as such* that cannot be totalised. I am not entirely convinced by Meillassoux's answer to the problem of ancestrality and the possibility of knowledge outside the direct experience of a thinking subject. Mathematics is contingent to thought and may be necessary to reality but such a perspective would at the very least force us to consider noise as, once again, remainder, disturbance, interference or chance. As we have seen, the narrowness of such a definition of noise bare its fruits only in so far discourse gravitates around an idea of noise in opposition to structure, chance (i.e. mathematics) and more in general in opposition to what is known, knowable, speakable of and perceiveable. I have instead presented noise under a different light while attempting to stress that such a diverse understanding of noise is not necessarily extraneous to Shannons' work, perhaps only hidden beneath its text. I stated that noise is pervasive in any communication process so as to make any signal the negative image emerging from noise. Noise, I stress once again, is not disturbance or interference but simply *what is*, while communication is what we can know with an approximate degree of certitude. This in turn means that we could not know anything if noise did not permeate what we know. Hence, noise is not the hinder-side of what we know, the unknowable or the unspeakable of. Rather, noise is intrinsic to what we know. Without noise we would not know. Without a positive noise there would be no negative image to look into - no negative knowledge or logos. Without noise there would be no knowledge of the experience while all experience, the non-repeatable stream of events we live without their conscious appraisal - the *once-occurent event of Being* in Bakthin [1] -, belongs to noise.

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